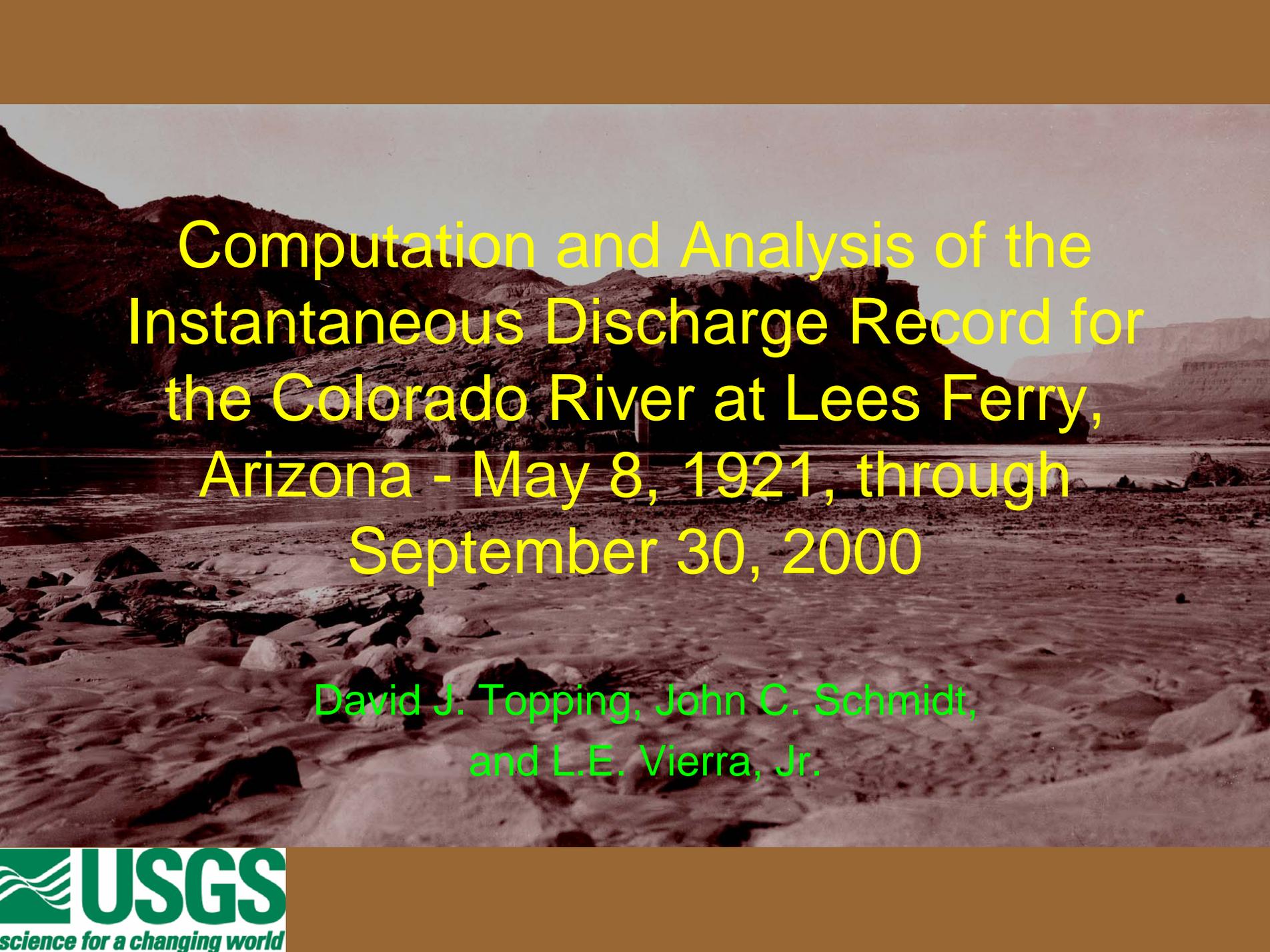


# Action Requested From AMWG

- **NONE**, These Two Presentations Are For Information Transfer Only

The information is derived from a multi-year synthesis research effort related to existing data on flow, sediment-transport and geomorphology associated with fine-sediment resources of the Colorado River Ecosystem, below Glen Canyon Dam.



Computation and Analysis of the  
Instantaneous Discharge Record for  
the Colorado River at Lees Ferry,  
Arizona - May 8, 1921, through  
September 30, 2000

David J. Topping, John C. Schmidt,  
and L.E. Vierra, Jr.

# Objectives

- Evaluation of the natural hydrologic variability in the Upper Basin as measured in the discharge of the Colorado River at Lees Ferry (42-year period from May 1921 to March 1963; only 10-15% virgin flow depleted prior to 1963, mostly before 1921)
- Evaluation of the effects of the operation of Glen Canyon Dam on the discharge of the Colorado River in Grand Canyon National Park (37-year period from March 1963 through September 2000)
- Implications for sediment transport and storage in the reach between Lees Ferry and the Grand Canyon gaging station

# Chief analyses

- Flow duration (with sediment transport implications)
- Sub-daily discharge variability
- Flood frequency

# Main problem to overcome

Data were of differing precision during different time periods

- May 8, 1921 through June 12, 1921  
not published
- June 13, 1921, through September 30, 1986  
mean daily
- October 1, 1986, through May 31, 1998  
30 minutes
- After June 1, 1998  
15 minutes

Retrieve and compile digitally all raw data collected by the USGS at the Lees Ferry and Grand Canyon gaging stations

4 years of work

Lees Ferry - May 1921 through September 1986

35 boxes of data in the Federal Records Center

Grand Canyon - November 1922 through September 1986

-Construct a continuous record of instantaneous stage

-Enter staff gage data from May 8, 1921, through January 18, 1923

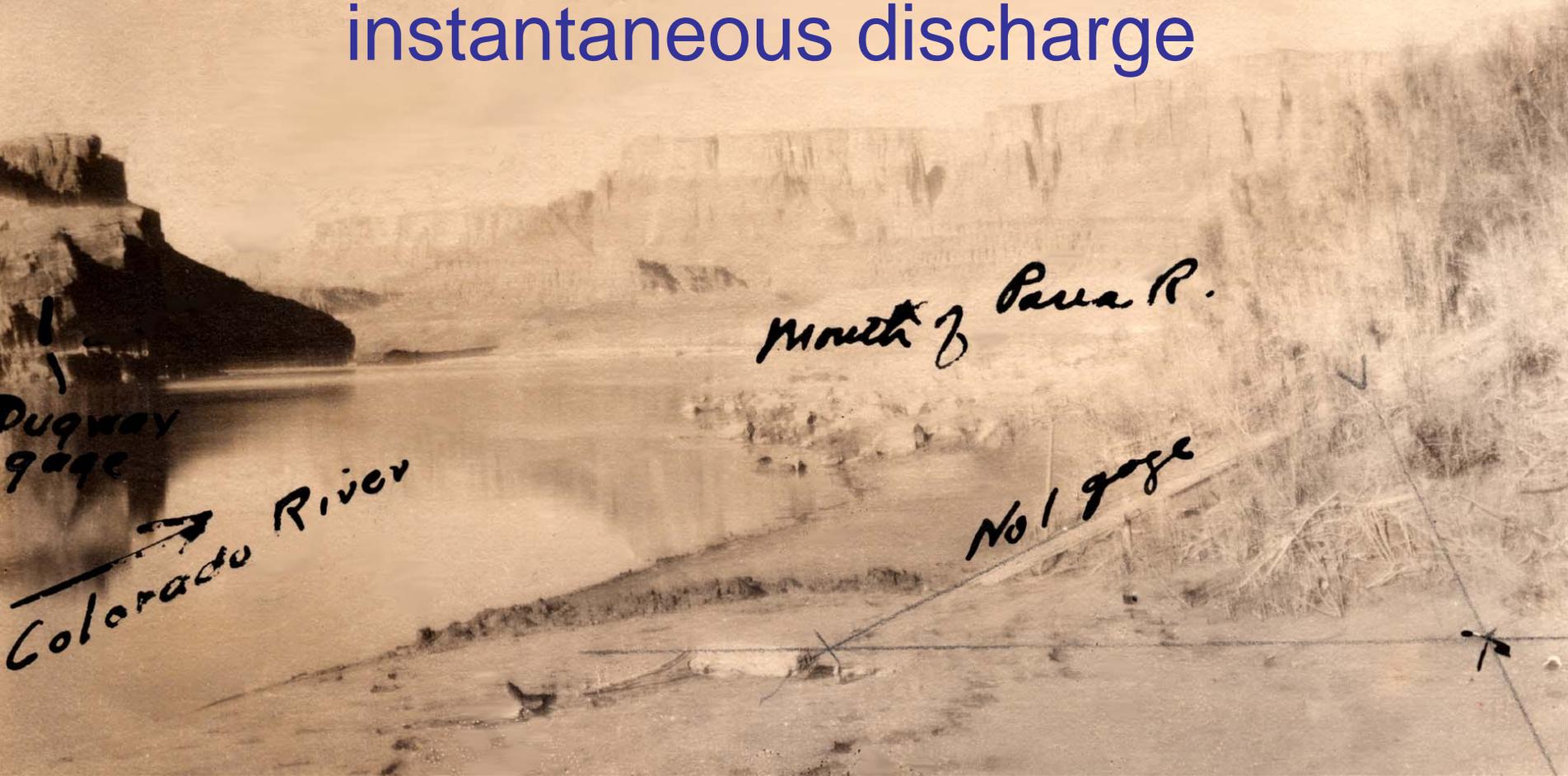
-Digitize strip-chart data from January 19, 1923, through September 30, 1986

-Enter digital-recorder data from February 2, 1967, through September 30, 1986

-Compute a continuous record of instantaneous discharge using the appropriate rating curves and shifts

-Quality control

# The continuous record of instantaneous discharge



Dugway  
gage

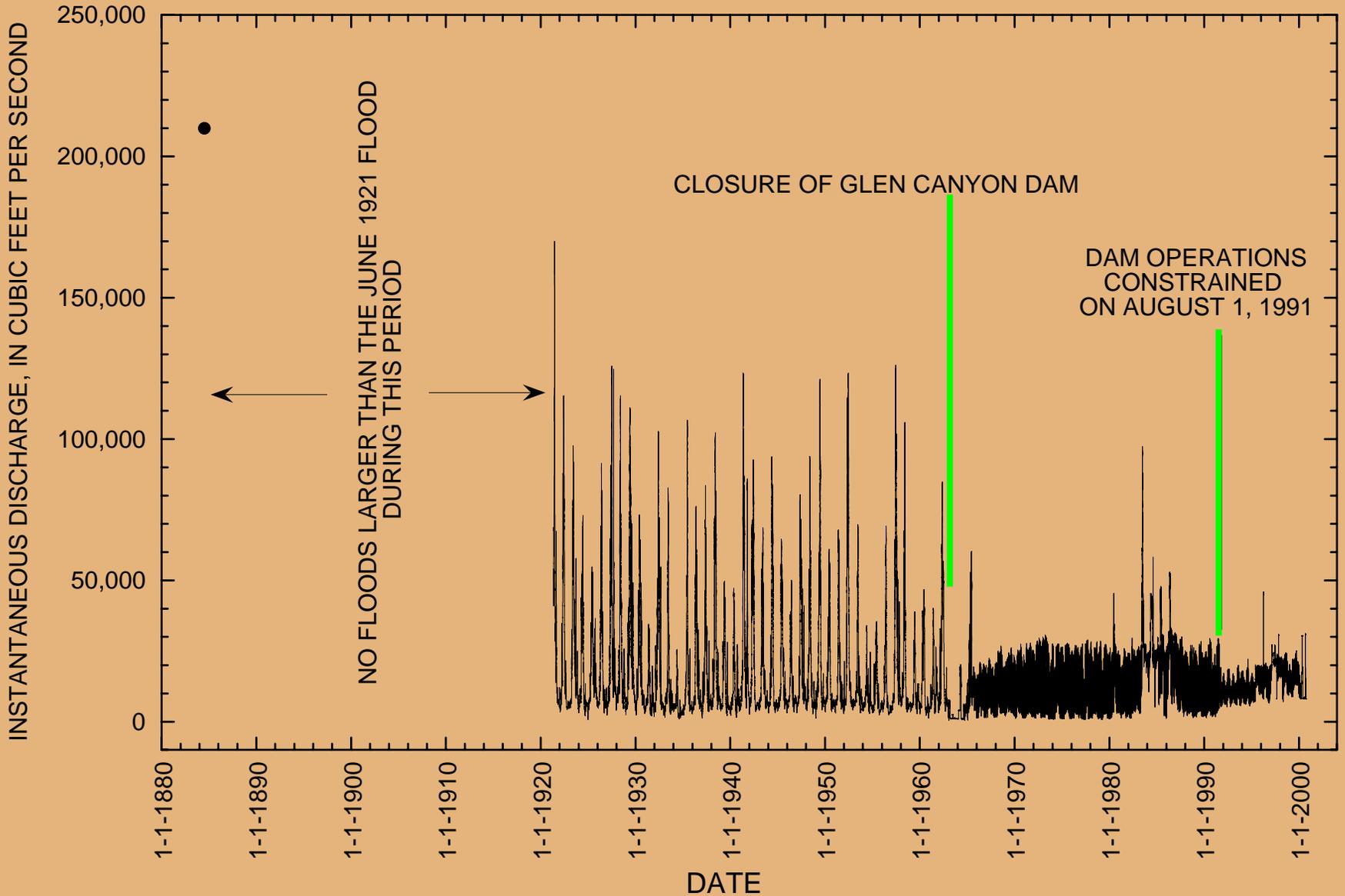
→ Colorado River

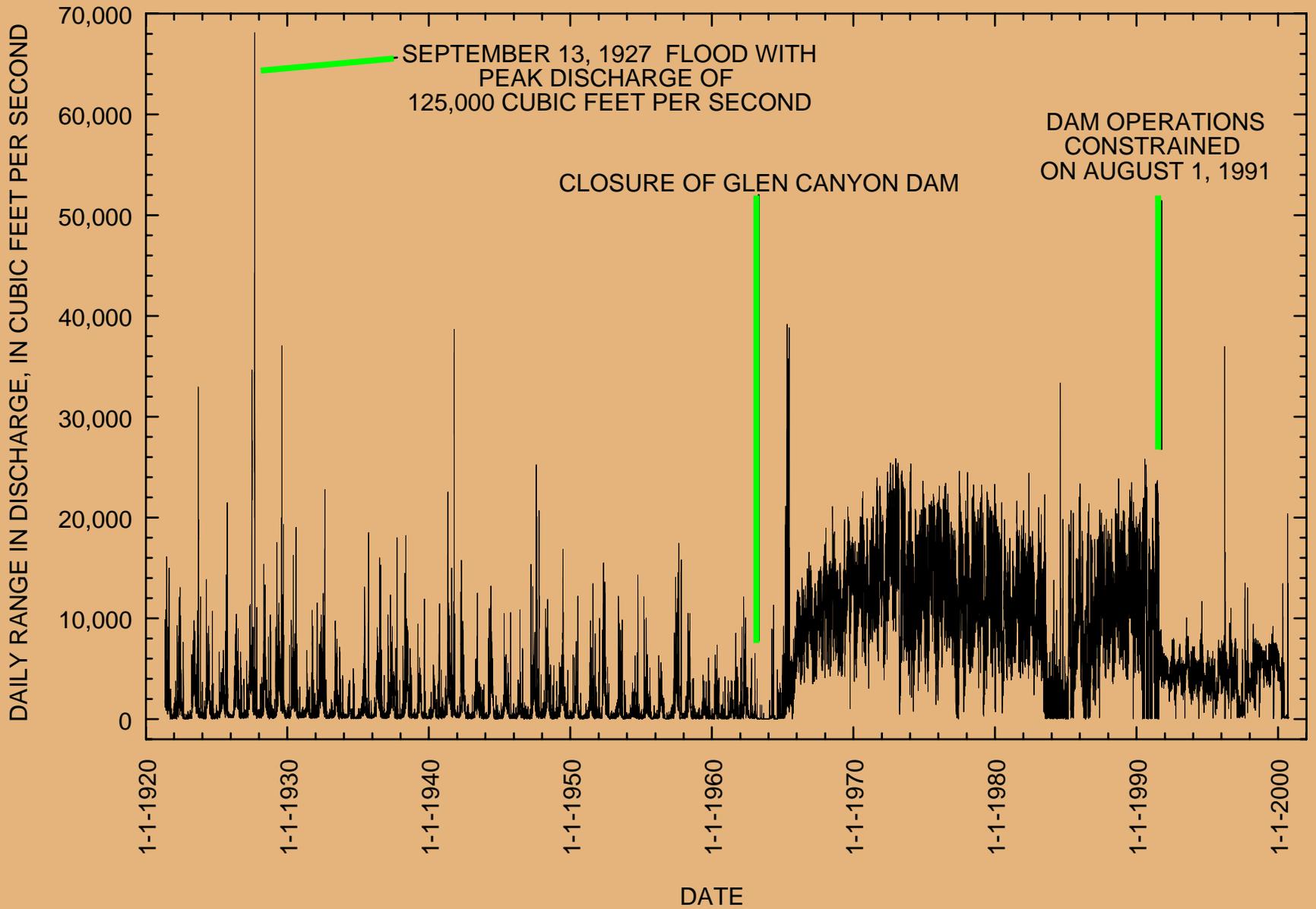
Mouth of Paria R.

No 1 gage

# EXPLANATION

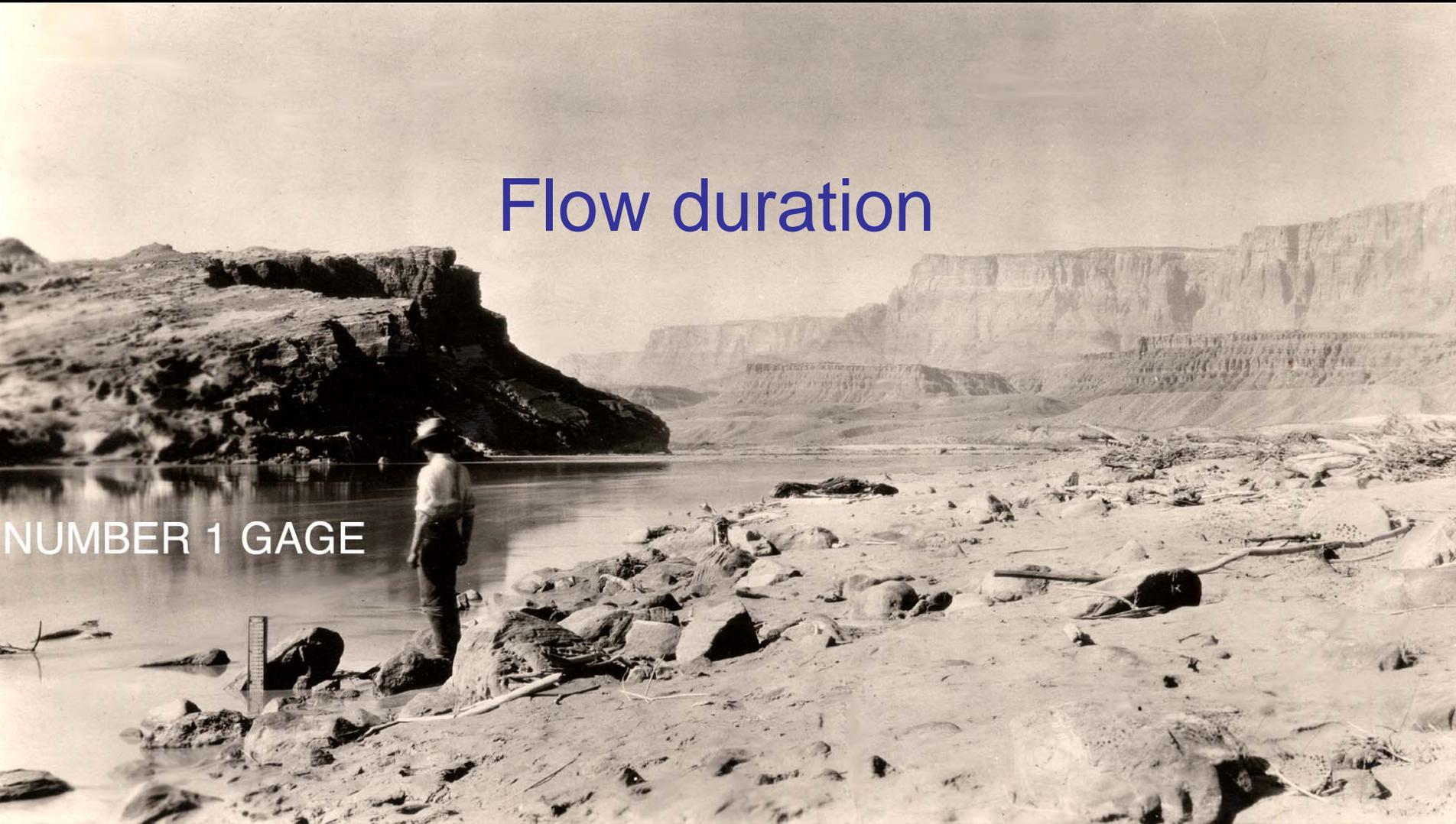
- MAY 8, 1921 - SEPTEMBER 30, 2000, CONTINUOUS RECORD OF INSTANTANEOUS DISCHARGE
- PEAK DISCHARGE OF THE 1884 FLOOD





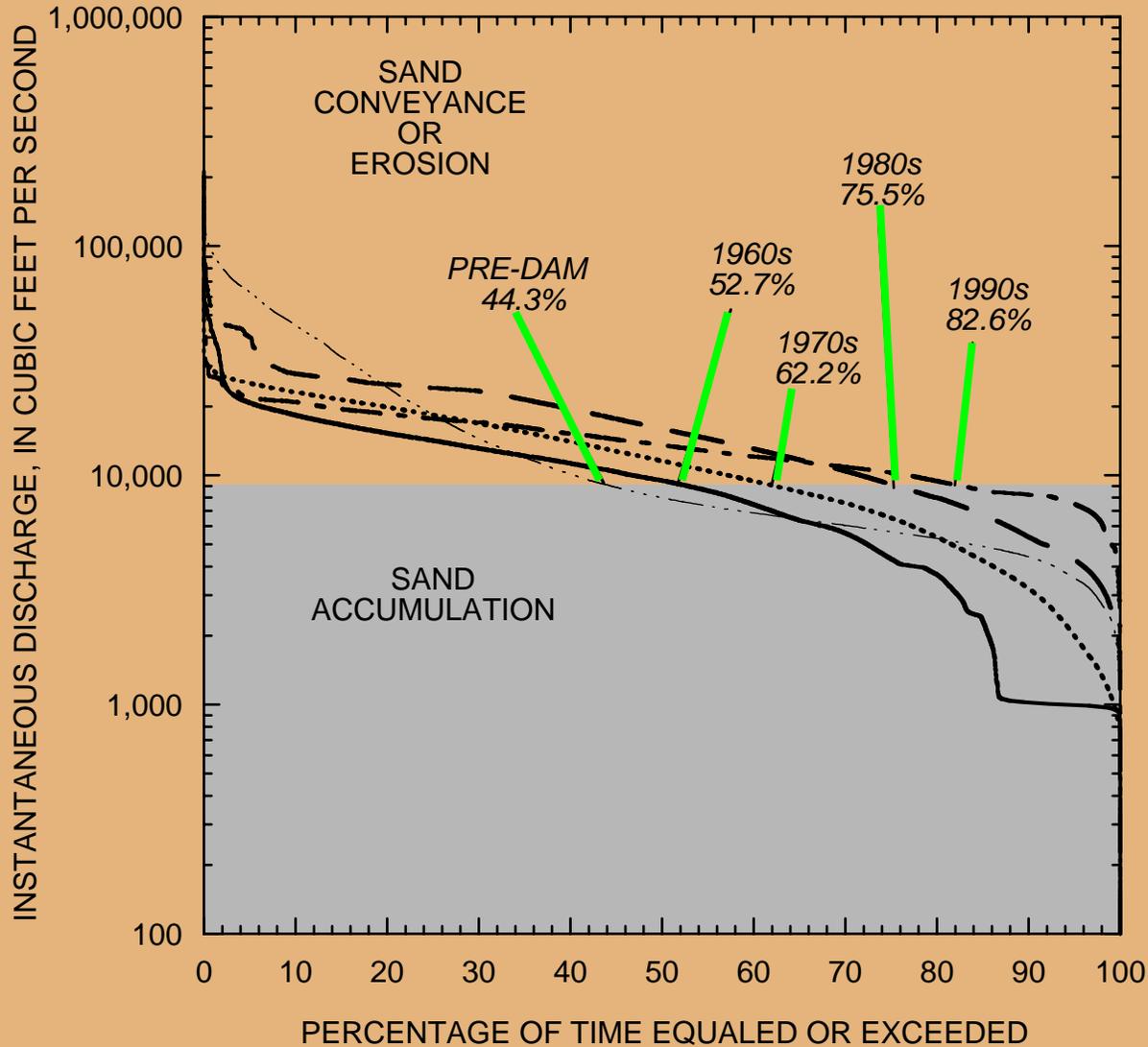
# Flow duration

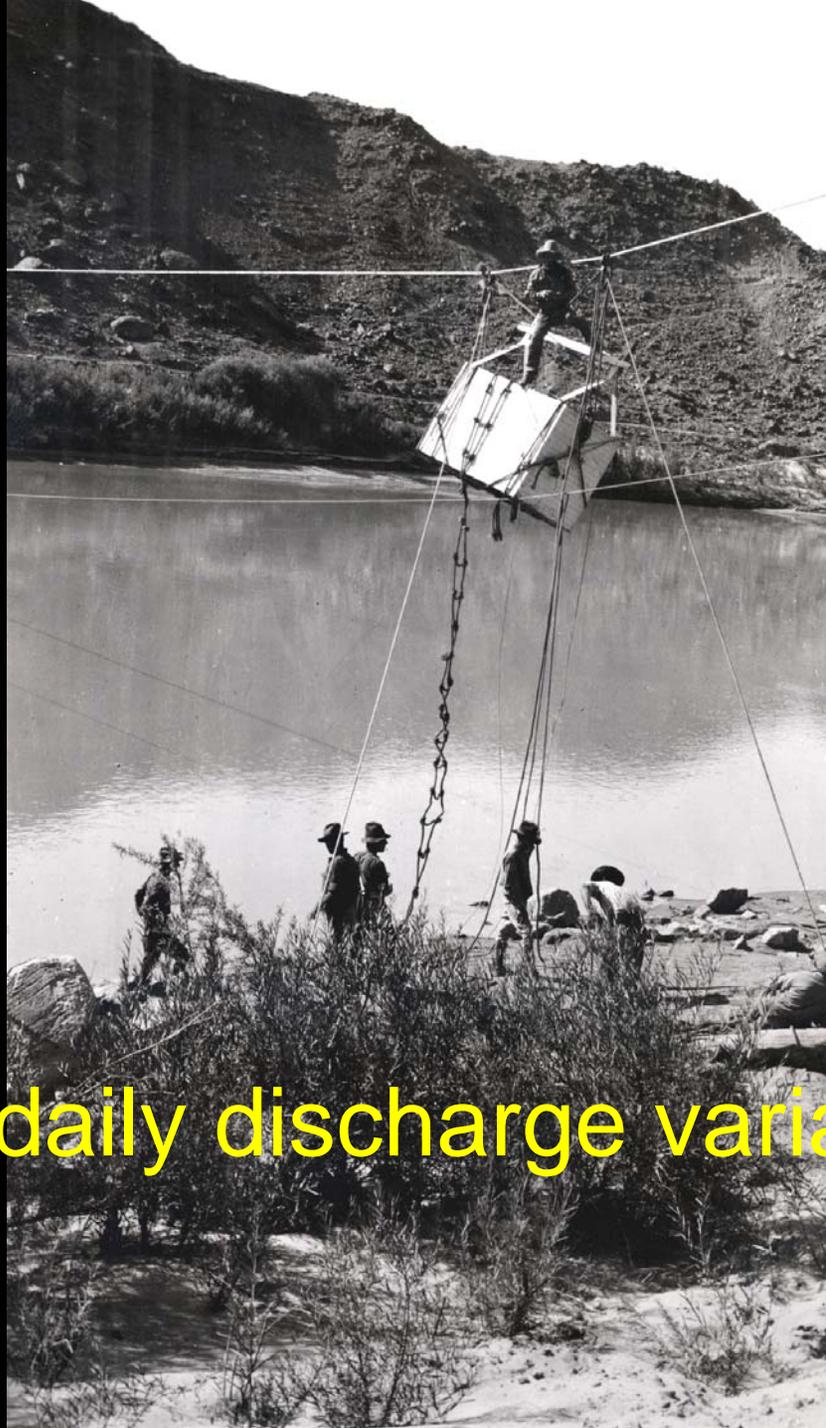
NUMBER 1 GAGE



# EXPLANATION

- 1960s (March 14, 1963, through December 31, 1970)
- ..... 1970s (January 1, 1971, through December 31, 1980)
- - - 1980s (January 1, 1981, through December 31, 1990)
- - - 1990s (January 1, 1991, through September 30, 2000)
- · - · - PRE-DAM (May 8, 1921, through March 12, 1963)



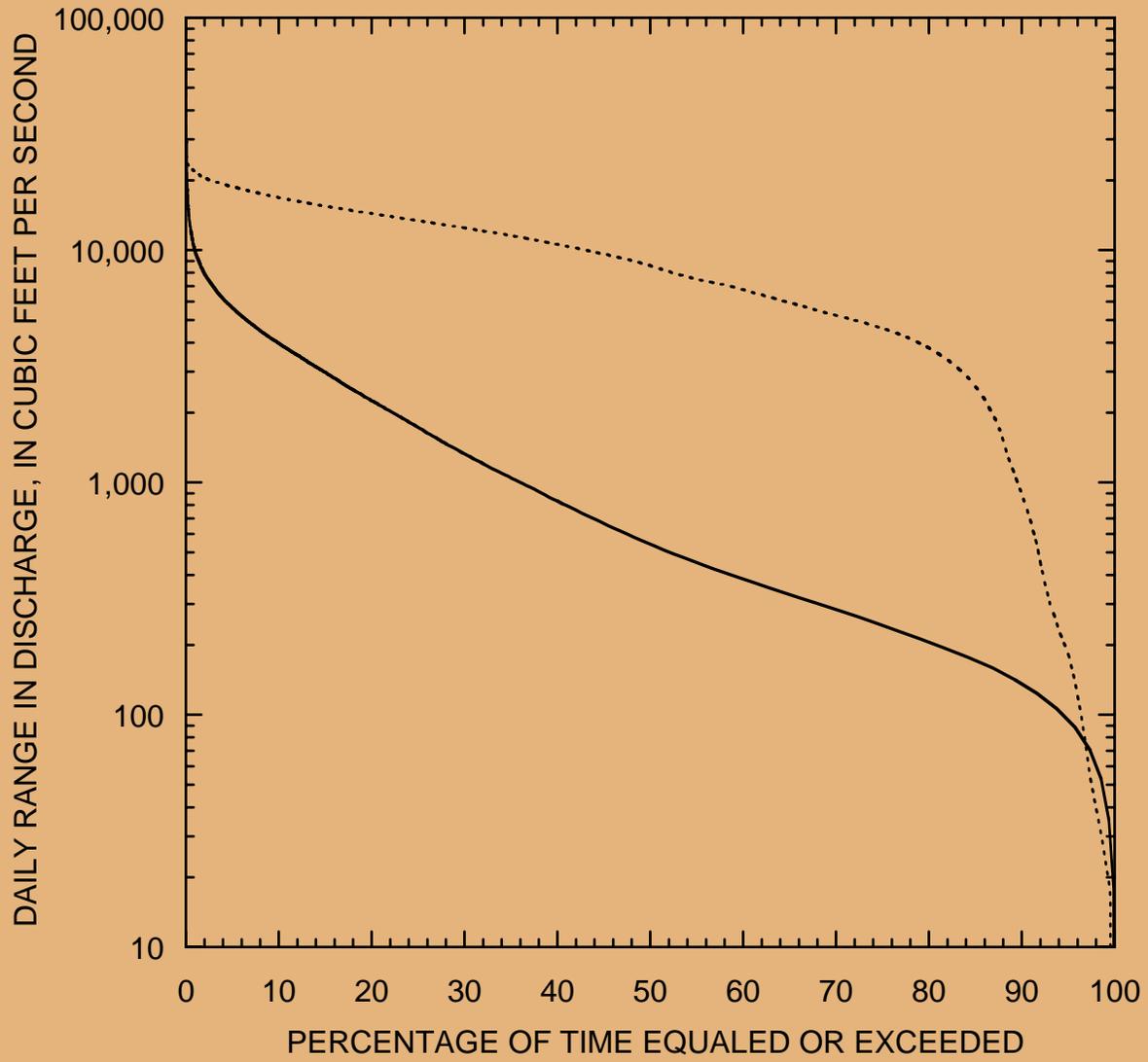


Sub-daily discharge variability

# EXPLANATION

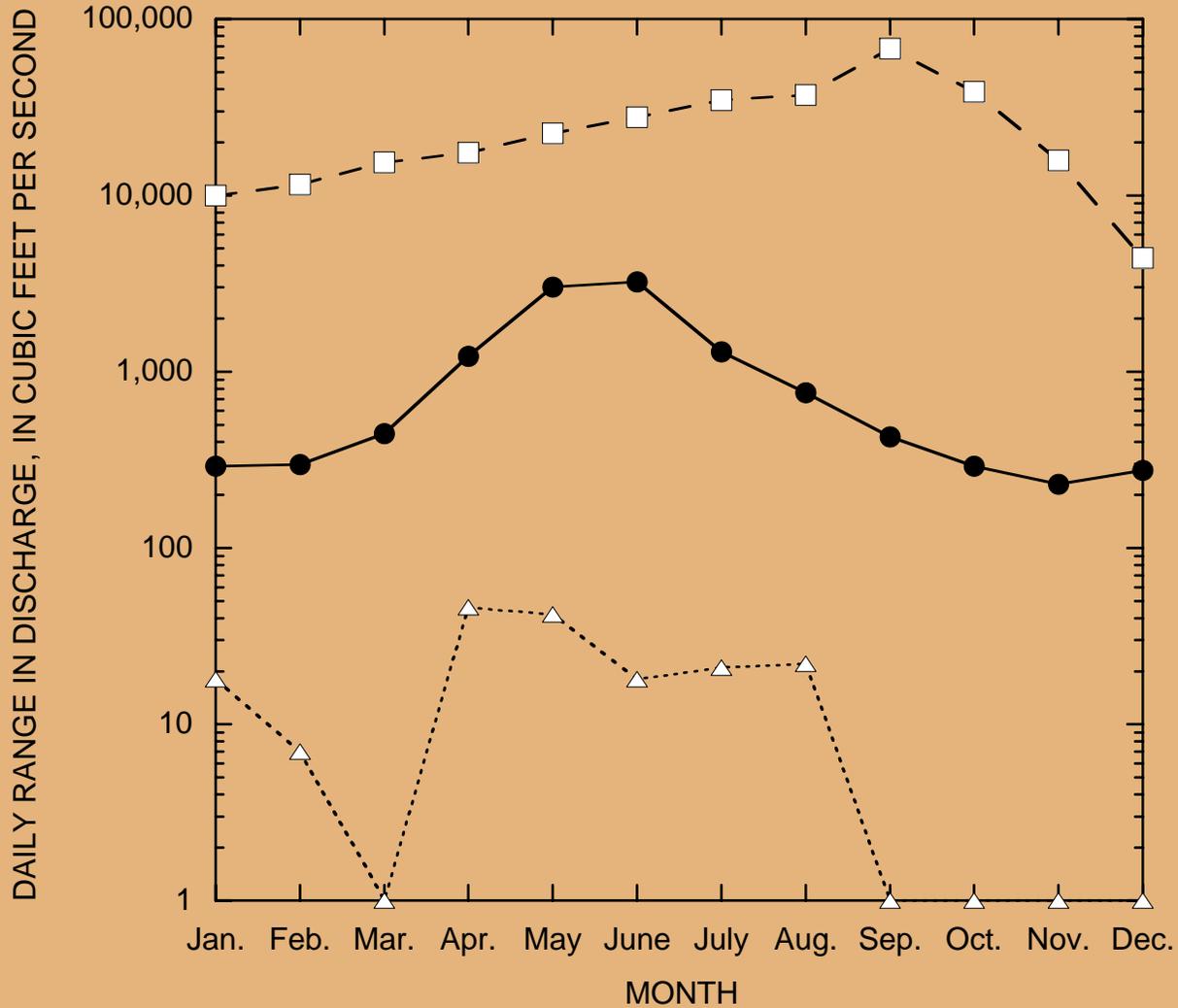
— PRE-DAM (May 8, 1921, through March 12, 1963)

..... POST-DAM (March 14, 1963, through September 30, 2000)

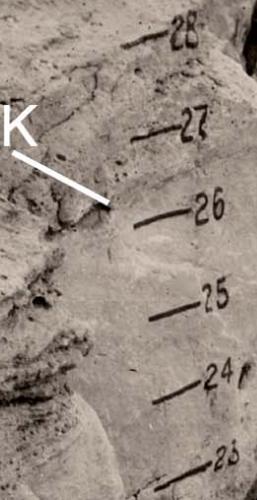


# EXPLANATION

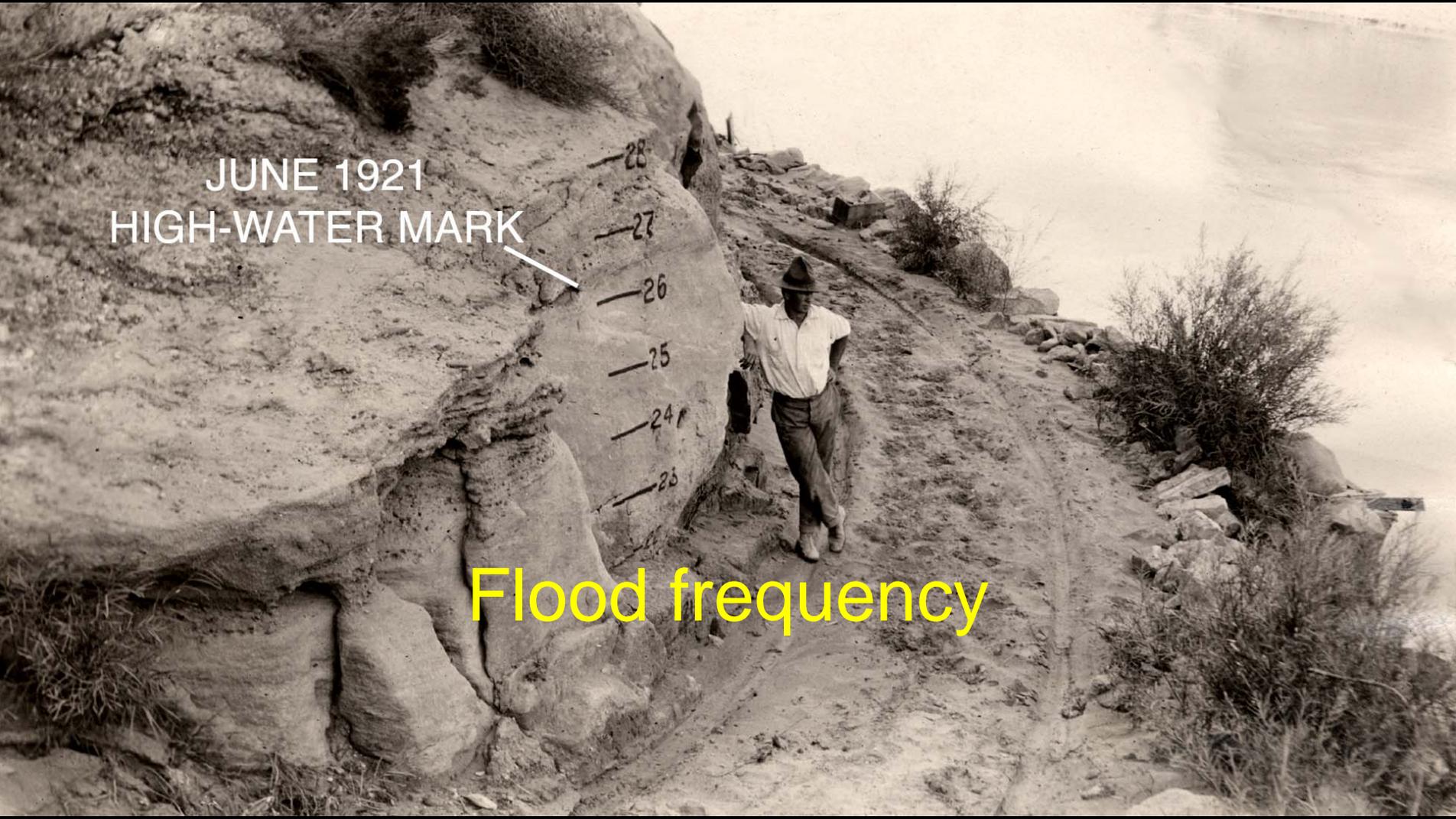
- PRE-DAM MONTHLY MEDIAN DAILY RANGE IN DISCHARGE
- ▲ PRE-DAM MONTHLY MINIMUM DAILY RANGE IN DISCHARGE
- PRE-DAM MONTHLY MAXIMUM DAILY RANGE IN DISCHARGE

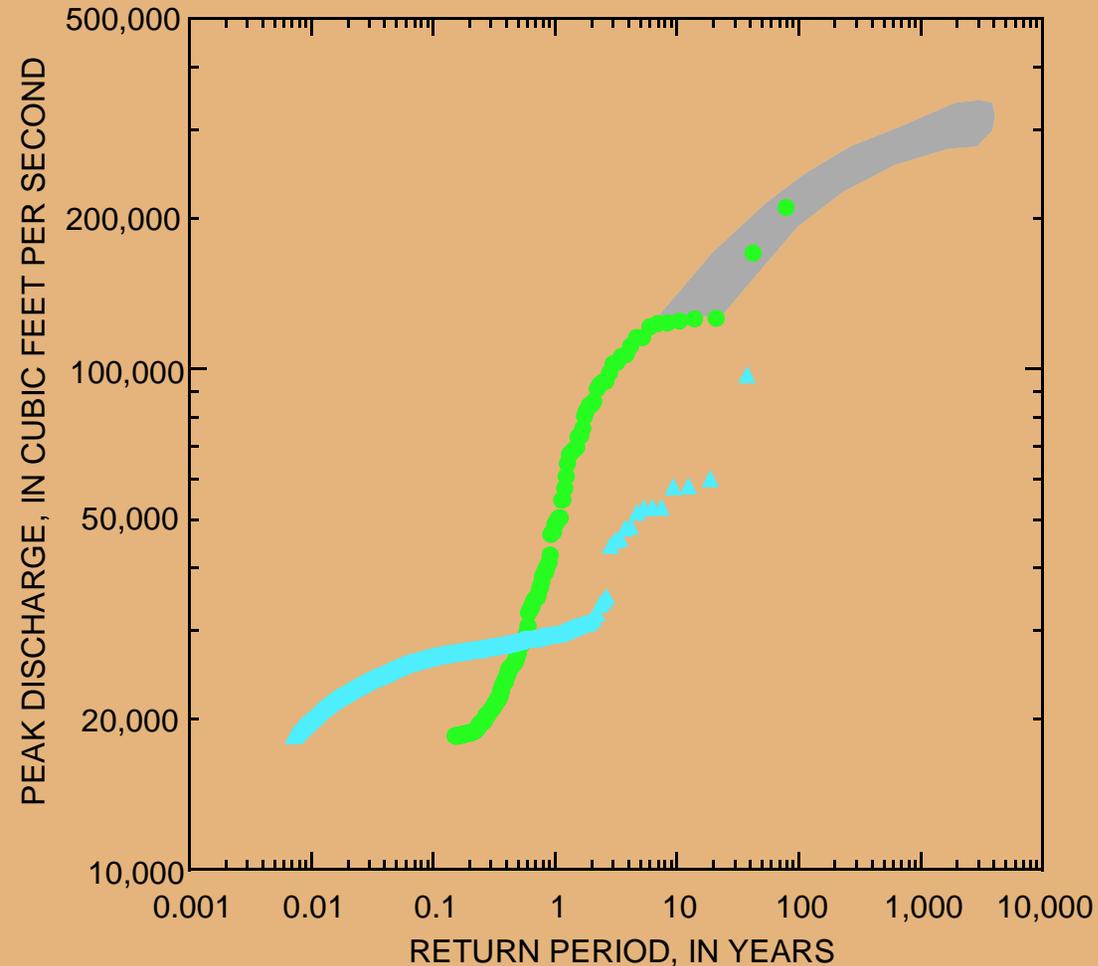


JUNE 1921  
HIGH-WATER MARK



Flood frequency





**PRE-DAM**  
 1 yr - 50,000 ft<sup>3</sup>/s  
 2 yrs - 85,000 ft<sup>3</sup>/s  
 6 yrs - 120,000 ft<sup>3</sup>/s

**POST-DAM**  
 1 yr - 29,500 ft<sup>3</sup>/s  
 2 yrs - 31,500 ft<sup>3</sup>/s  
 6 yrs - 52,800 ft<sup>3</sup>/s

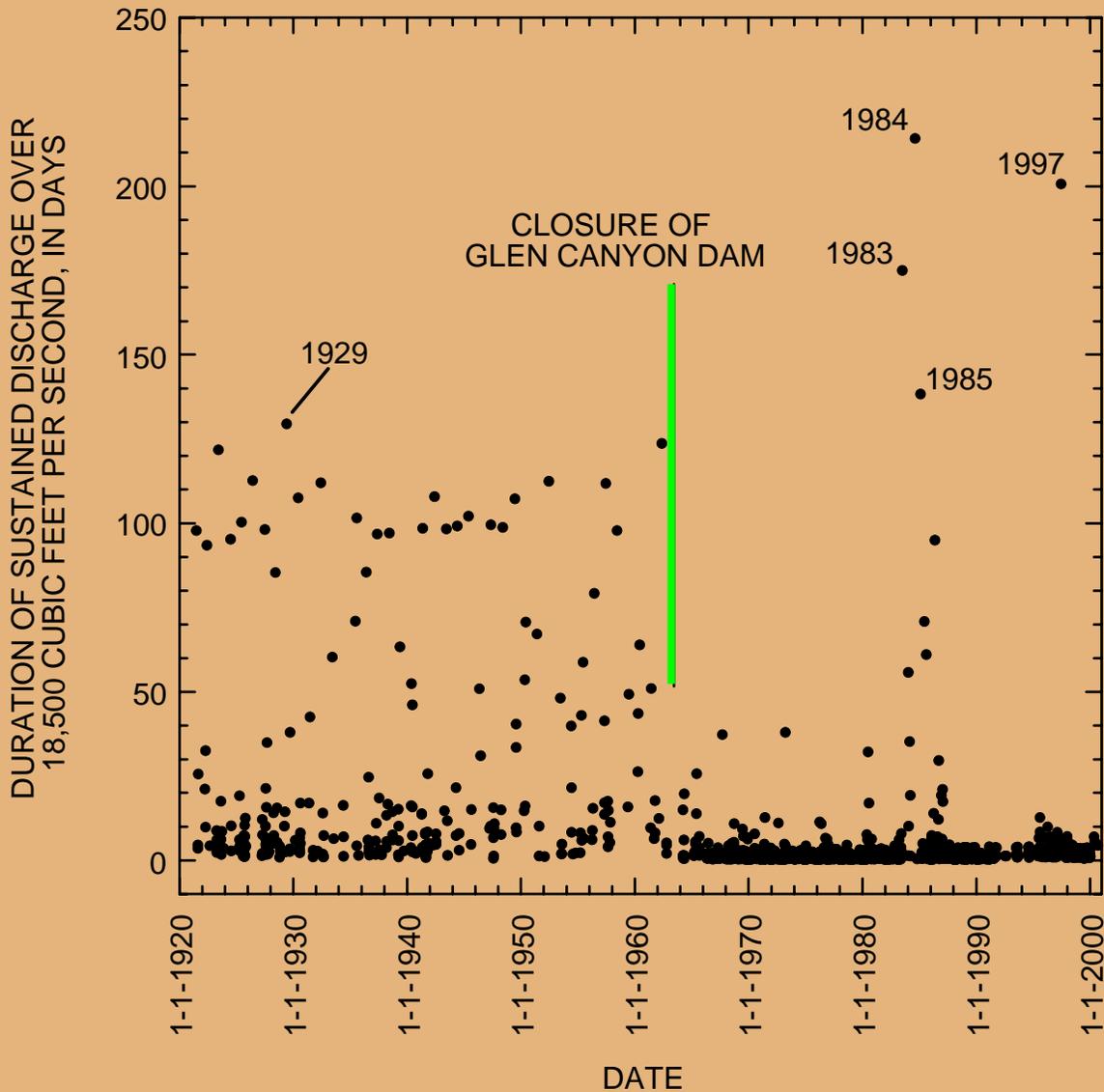
**EXPLANATION**

- PRE-DAM PARTIAL-DURATION FLOOD SERIES
- ▲ POST-DAM PARTIAL-DURATION FLOOD SERIES
- UPWARD EXTENSION OF PRE-DAM PARTIAL-DURATION FLOOD SERIES BASED ON THE PALEOFLOOD DATA COMPUTED FROM THE REVISED DISCHARGES AND ADJUSTED RETURN PERIODS FROM THIS STUDY

**PRE-DAM**  
 20,000 ft<sup>3</sup>/s - 97 days  
**POST-DAM**  
 20,000 ft<sup>3</sup>/s - 3.6 days



Duration of sustained high flows



4 LONGEST PERIODS OF SUSTAINED HIGH DISCHARGE OCCURRED AFTER CLOSURE OF THE DAM

# Conclusions --- pre-dam

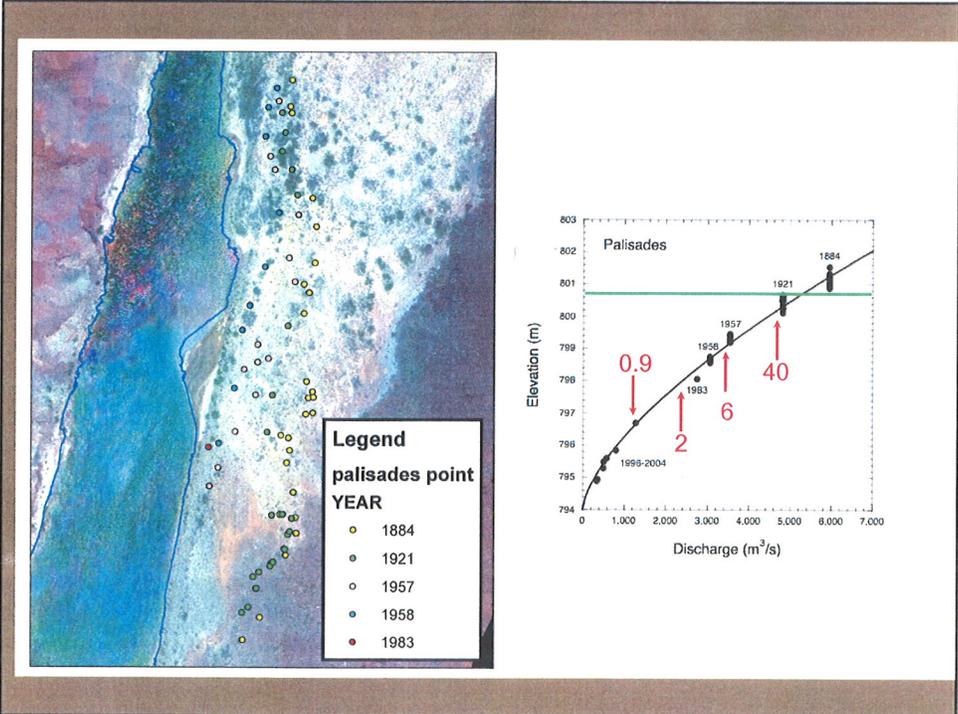
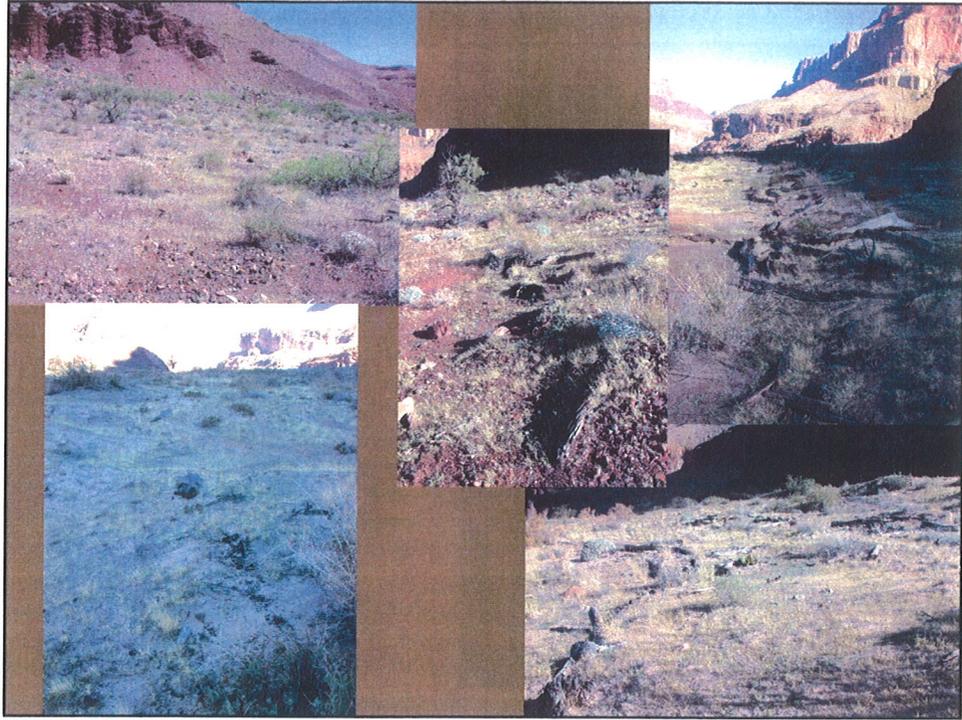
- Median discharge = 7,980 ft<sup>3</sup>/s
- Median daily range in discharge 542 = ft<sup>3</sup>/s
- Wettest decade---1920s---median discharge 10,700 ft<sup>3</sup>/s , median daily range in discharge 808 ft<sup>3</sup>/s
- Driest decade---1930s---median discharge 6,720 ft<sup>3</sup>/s , median daily range in discharge 516 ft<sup>3</sup>/s
- Flows conducive to sand accumulation occurred 55.7% of the time between 1921 and 1963, with the 1930s likely being the decade most dominated by sand accumulation
- Discharges in excess of 18,500 ft<sup>3</sup>/s occurred only 25% of the time pre-dam
- Daily ranges in discharge exceeded 10,000 ft<sup>3</sup>/s only during 1% of all pre-dam days and exceeded 30,000 ft<sup>3</sup>/s during 1 day every 3 years (during summer and early fall)
- On average, floods with peak discharges of 50,000 ft<sup>3</sup>/s occurred every year, floods with peak discharges of 85,000 ft<sup>3</sup>/s occurred every 2 years, and floods with peak discharges of 120,000 ft<sup>3</sup>/s occurred every 6 years

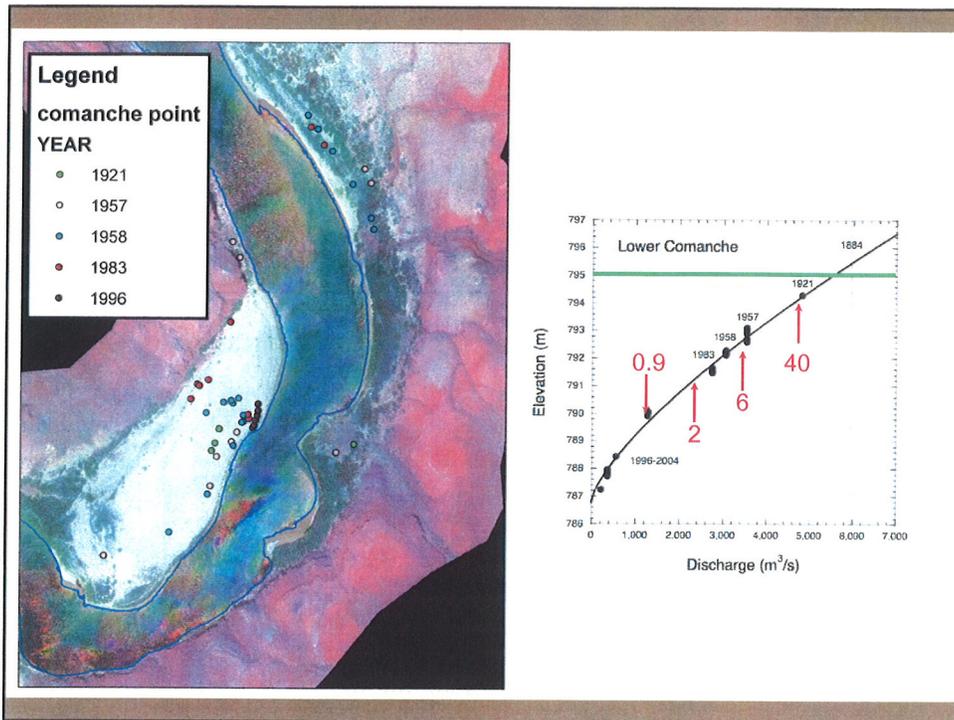
# Conclusions --- post-dam

- Median discharge -- 1960s = 9,490 ft<sup>3</sup>/s --- 1990s = 13,500 ft<sup>3</sup>/s
- Dam operations have largely eliminated base flows; pre-dam minimum discharge = 483 ft<sup>3</sup>/s; pre-dam discharges < 5,000 ft<sup>3</sup>/s 32.7% of the time
- Median daily range in discharge has increased by a factor of 15.8 relative to pre-dam; post-dam median daily range (8,580 ft<sup>3</sup>/s ) exceeds pre-dam median discharge (7,980 ft<sup>3</sup>/s )
- Post-dam daily range in discharge exceeds pre-dam daily range in discharge except during 0.1% of all pre-dam days
- Flows conducive to sand accumulation have progressively disappeared; discharge exceeded 9,000 ft<sup>3</sup>/s --in 1960s, 52.7% of the time--in 1970s, 62.2% of the time--in 1980s, 75.5% of the time--in 1990s, 82.6% of the time
- Dam operations have maintained the frequency of floods with peak discharges of 29,000 ft<sup>3</sup>/s, have decreased the frequency of floods with larger peak discharges, and have greatly increased the frequency of “smaller” floods
- Pre-dam 2-year flood = 85,000 ft<sup>3</sup>/s ; post-dam 2-year flood = 31,500 ft<sup>3</sup>/s
- Recurrence interval of 20,000 ft<sup>3</sup>/s flood -----97 days pre-dam, 3.6 days post-dam (factor of 27 increase)
- Longest 4 periods of sustained high discharge all post-date the dam: 1984, 1997, 1983, 1985

# Summary of Knowledge

- Substantial natural variability existed in discharge and in the daily range in discharge over decadal timescales prior to construction of the dam
- Changes imposed on the hydrology by dam operations exceed anything in the quasi-natural pre-dam period of record; seasonality removed from both discharge and the daily range in discharge





## More conclusions

- Largest flood in the 80-year period prior to 1963 would completely fill many arroyos
- Pre-dam floods with 6-year recurrence interval would deposit 4-5 m of sand in lower portions of arroyos
- Flood deposits are common up to stage of 1921 flood, some deposits 4,500 years old
- Flood deposits above stage of 1884 flood are rare; now have 4 likely occurrences of 1,200-1,600 year old ~300,000 ft<sup>3</sup>/s flood (RM 2, 70.5, 73, 88)